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ABSTRACT

An experimental program in mathematics at a high school in Watts, California, demonstrated that multilevel team teaching and individualized instruction produced significantly higher student achievement in computational skills than did traditional methods, and at no increase in cost. The program was developed to improve the basic mathematics skills of high school students from a ghetto area who are unable to begin secondary-level math courses because of deficiencies in computational skills. The multilevel team consisted of a teacher, a teaching assistant (a college junior or senior), and a student assistant. The only teaching done by the teachers or teaching assistants was done individually in response to a student question. On a standardized math test, the experimental group was found to improve an average of 2.16 points more (about two-fifths of a semester in grade level) than control group students with the same starting scores, a statistically significant improvement. The major accomplishment of the course was to halt the further retardation of the students; however, a system still needs to be developed which will reduce the gap between the students' grade level and their mathematics achievement level. (Author/JK)

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A SYSTEM FOR INDIVIDUALIZED MATH INSTRUCTION IN SECONDARY SCHOOLS

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ABSTRACT

An experimental program in mathematics at David Starr Jordan High School in Watts demonstrated that multilevel team teaching and individualized instruction produced significantly higher student achievement in computational skills than did traditional methods, and at no increase in cost. Forty-five students in the experimental program were tested against forty-five control group students in traditional classrooms for improvement in computational skills. On a standardized math test, the experiment group was found to improve an average of 2.16 points more (about 2/5 of a semester in grade level) than control group students with the same starting scores. The difference in mean improvements was found to be significant at a 95% level of confidence.

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Background

The math students in secondary schools in ghetto areas are retarded in their mathematical development. Such schools have unusually large numbers of students who are not able to begin Algebra because they lack computational skills. Traditionally, these students have been grouped into classes called Basic, General, or High School Math. While all students in these classes are unable to begin Algebra, there is still a wide variance in their level of mathematical achievement. Some students have not mastered their multiplication facts, many cannot utilize the division algorithm, and most cannot perform operations with fractions. Virtually none are able to solve problems involving percent notation.

Lecturing to a random group of 30 such students can be frustrating for both the teacher and the students. Due to the large variance in skill level, a lecture on any topic will necessarily be beyond the state of readiness for many, and a redundancy for others. Only a few students will be at the proper state of development for the topic being presented. One common solution to this problem has been to begin each semester at the beginning of mathematics with the concept of number, and teach all topics in sequence until all the computational skills have been covered. This approach would be satisfactory if the students knew nothing of the subject matter and a large amount of time was available. However, the students have had at least 9 years of mathematics before they arrive in high school. Many of the students find such an approach boring and quickly tune out. Those who have not yet learned the material find the pace too fast and fail to master it.

Individualized Instruction

The solution employed at Jordan High School was individualized instruction by multi-level team teachers. A teacher, a teaching assistant, and a student assistant were assigned to each classroom. (Teaching assistants were college students in their junior or senior year. They were paid $2.55 per hour.) The only teaching done by the teachers or teaching assistants was done individually in response to a student question.

At the beginning of the semester each student was tested by means of a locally designed survey test in the basic computational skills. On the basis of the survey test, the students were divided into three approximately equal groups in separate classrooms. Each room was equipped with the materials for a portion of the total course. The lowest room contained materials for addition, multiplication tables, and multiplication skills. The middle room had subtraction, estimation and comparison and division. The highest room had fractions, decimals, and percent.

Upon reaching their assigned rooms, each student was given a diagnostic test at the level of the first skill missed on the survey test. The diagnostic tests used were from the Science Research Associates (SRA) Computational Skills Kit. These tests measure each component skill of a computational skill. For instance, the diagnostic test for multiplication of whole numbers contains questions on sub-skills ranging from multiplication by one digit without regrouping, and multiplication by one digit with regrouping, to multiplication of a three-digit number by a three-digit number. Included are problems involving all the common errors with zeros. On the basis of the diagnostic test, a record sheet was made for each student. The record sheet showed which skills were missed on the diagnostic test and served as an outline of what the student was expected to accomplish.

Corresponding to each problem on the diagnostic test is a card of about 30 problems of the same type with the correct solution on the back. The SRA cards were used for teaching whole number arithmetic. The student was given the card for the first problem he missed. A TA or teacher showed him how to work the problem correctly and the student was told to work enough problems from the card so that he felt he could work any problem of that type. He was then to cross that number off his record sheet. Crossing off the number was a student's responsibility rather than an instructor's responsibility, on the theory that only the student could make this judgment. When all cards for a particular skill had been crossed off, the student was given a progress test (an alternate form of the diagnostic test) to evaluate his progress and provide protection against failure experiences. If he did well, he was given an achievement test for credit; if he did poorly, the progress test provided a new diagnostic instrument to recommend further study. One of the early lessons learned in the pilot phase of this project was that if the student did poorly with a particular set of materials, repeating that sequence would be of little value. Therefore, an effort was made to develop at least one alternate route to mastering each skill.

An alternate route which proved effective with students who could read was Lessons for Self Instruction. This was a kit of branching programs for addition, subtraction, multiplication, and division at several levels of difficulty from third to tenth grade.

Most students learned fractions from a 47 page series of semi-programmed exercises written during the summer before the experiment. Decimals and percent were learned from TEMAC Basic Mathematics Book 4*. The SRA diagnostic tests were used to evaluate achievement and provide an alternate route in fractions, decimals, and percent. These materials were either written or selected by the authors during the summer following the pilot phase and preceding the experiment. This extensive planning and preparation was made possible by the sponsorship of TRW Systems Group. During the experiment, two engineers from TRW served as volunteer classroom assistants one morning a week when their schedules permitted.

The problem of assigning grades was resolved by preparing two "grade contracts", one for students qualifying on their pretest for High School Math, and one for students qualifying for Basic Math. Progress was measured according to achievement and midcourse tests passed. Additional credit was given for maintaining high grades on the tests, and for diligence as evaluated by the teacher. The main emphasis in grading, however, was on goals achieved. At any time during the semester a student could evaluate his progress towards a passing or better grade at midterm and at the end of the semester by referring to his grade contract.

Experiment Design

To test whether the new system of individualized math instruction produced more improvement in math skills than traditional methods, a comparison was made between students in the experimental group and students in a control group of standard math classes. At the beginning of the semester, two different forms of the California Arithmetic Test, Junior High Level, were administered to both groups of students. The improvement in scores for each student, d_i, was computed. In all, 47 pairs of before and after scores were obtained for the control group and 133 pairs were obtained for the experiment group.

* In the semester following the experiment, Book 7 Programmed Math by Sullivan Associates replaced TEMAC for decimals.

Improvement of Total Populations

The mean increases in score, $\bar{d}$, for the two entire groups were as follows:

Experiment	$\bar{d} = 4.82$	$n = 133$
Control Group	$\bar{d} = 2.53$	$n = 47$

At the grade levels involved, a 5 point improvement in score constitutes a one semester improvement in math ability. To ascertain whether these improvements were significant statistically, the student's t test for paired scores[1] was applied. The null hypothesis (H_o) was that the student's score at the end of the semester was the same as the score at the beginning of the semester. For both groups, the improvement was found to be significant at the 95% level of confidence:

Experiment:	$t = 3.68$	$t_{.95} = 2.00$	$t > t_{.95}$	Reject H_o
Control:	$t = 2.77$	$t_{.95} = 2.53$	$t > t_{.95}$	Reject H_o

Note that the t for the experiment group exceeded the cutoff for a 95% level of confidence by a large amount. The results indicate that indeed some improvement occurred in each group in the course of a semester's study.

Comparison of Experiment and Control Groups

Because the experiment group contained both basic math and high school math students, while the control group contained only high school math students (the more advanced math subject), it was necessary to select from the experiment group a set of students having comparable initial test scores to those in the smaller control group. Random numbers were assigned to experiment group scores, and where several scores were available to match one control group, that with the lowest random number was assigned. When no score identical to the control group score was available, a score one point higher or one point lower was chosen. For each higher score, a lower score was chosen elsewhere, so that the average starting score for the two matched groups was identical. It was possible to match 45 of the 47 control group scores. Two control group scores had no experiment group score within one point, and were left unmatched. For the two groups of matched scores, the mean increases were as follows:

1 See Mathematical Tables from Handbook of Chemistry and Physics, 10th Edition, pp. 215-217, and A. Hald, Statistical Theory with Engineering Applications, New York, Wiley, 1962, pp. 401-8.

Experiment: $\bar{d}_e = 4.80$

Control: $\bar{d}_c = 2.64$

Difference: $\bar{d}_e - \bar{d}_c = 2.16$

The experiment group increased 2.16 more points on the average than did the control group. This corresponds to about two-fifths of a semester in grade level. To ascertain whether the difference between the groups was significant, the student's t test for paired scores was applied for a 95% level of confidence. The null hypothesis (H_o) was that the mean improvement for the experiment group was the same as for the control group.

$$\bar{d}_e - \bar{d}_c = 2.16 \quad t = 1.80 \quad t_o = 1.68 \quad \text{Reject } H_o$$
$$\text{for } n = 45$$

Hence, the difference of 2.16 points (2/5 of a semester) constituted a significantly greater improvement in the skills of the experiment group than in the skills of the control group.

Cost Effectiveness

At first glance such a system may appear to involve considerable extra expense for personnel and materials. Teaching assistants (by city-wide policy) were paid only for the hours they actually worked and received no paid holidays. If all TA's had worked every possible hour, their total salary would have been $6,750 per year On this basis, they were hired in lieu of the fourth teacher that 105 students per period would normally require. The expenditure for special instructional materials was about $1,000, which compares favorably to the textbook expense for 315 students over the 3 semesters that the system has been in operation. In short, the system is more cost effective than the conventional classroom since it is teaching twice as much mathematics at the same cost. A major advantage of the system is its ability to tolerate a high absence rate among the students. Since students are working individually, they do not miss what was covered in class while they were absent.

Possibilities for Improvement

The average improvement of the experiment group students was almost twice that of the control group. Unfortunately, this does not mean the problem has been solved.

The average improvement of the experiment group students was about one semester, but the semester improvement only raised high school students from the 6.0 grade level to the 6.5 grade level. The major accomplishment was to halt the increasing retardation of the students. What is needed is a way to reduce the gap between the students' grade level and their level of achievement in mathematics. One possibility is to employ such a system at the Junior High or Elementary level, where the retardation is not so great. Three years of instruction with the system would mean three years advancement.

A second possibility for improvement is to computerize the management of the system so that teachers could spend more time assisting students with learning and less time correcting papers or telling students what to do next. One major difficulty with the present program is the problem of instructing teaching assistants and new teachers in choosing available materials to assist a student with each learning problem.